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(54) CONTACTLESS ROTOR ASSEMBLY

(71) We, DORNIER GMBH., formerly DORNIER A.G., a German company, of 799 Friedrichshafen/Bodensee, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a contactless rotor assembly.

In our co-pending Application No. 32128/72 (Serial No. 1382300) there is disclosed a contactless rotor assembly having an elongate rotor with a vertical axis of rotation and an electromagnetic support system for the rotor, the rotor being suspended by the magnetic action of the support system on a body which is connected to the upper end of the rotor. The rotor may be for example the rotor of a gas ultra-centrifuge. To be suspended by the magnetic support system, the rotor must be wholly or partly of ferromagnetic material.

In the assembly of our co-pending Application, the magnet support system includes an electromagnet, the distance between which and the rotor is maintained virtually constant by an electrical regulating system. A support system which is thus controlled may be referred to as an active support system, in contrast to a passive support system, for which there is no control.

Also as disclosed in our co-pending Application, for radial guiding of the rotor, a known oil-hydraulic permanent magnet system is used, so that in the radial direction the rotor has a passive guiding system. In addition an electromagnetic damping system damps high frequency nutational and/or processional motion of the rotor.

In practice, fresh limiting factors have appeared, and difficulties have arisen. This applies not only to a one-stage rotor, but particularly to a multi-stage rotor when over-critically operated, so that the system according to our co-pending Application no longer in all cases satisfies the increased operating requirements. A multi-stage rotor is one which in the axial direction is divided by flexible or articulated intermediate members. Such a sub-division is applied to a gas ultra-centrifuge, for instance, by folds in the rotor shell.

In an axially elongate rotor, particularly a multi-stage rotor, high radial guiding forces have to be applied when negotiating flexion-critical speeds and this is not possible with a passive guiding system. In addition, parts of the guiding system also rotate at the high rotor speed and can be so intensely stressed that complicated reinforcement is required. Further, parts of the guiding system are enclosed in oil-filled housing parts. In the event of a fault, this oil can escape and cause undesirable dirtying of the gas circuit in an ultra-centrifuge. Further, radial guiding of the rotor in only two planes normal to the rotation axis may not be adequate, particularly in the case of a multi-stage rotor. In some circumstances, even the positions of the radial guiding planes along the rotor axis is important.

It is an object of the invention to avoid, or at least reduce the effect of, the above-mentioned difficulties. According to this invention a contactless rotor assembly comprises an elongate rotor having a vertical axis of rotation, an electromagnetic support system for the rotor, and an electromagnetic radial guiding system, the rotor being suspended by the magnetic action of the support system on it, wherein

i) the electromagnetic support system is regulated in accordance with changes in the vertical position of the rotor;

ii) the electromagnetic radial guiding system provides guiding of the rotor in at least two vertical planes; and

iii) the electromagnetic radial guiding system is regulated in accordance with changes in radial position of the rotor.

It is thus possible to avoid feed-back between the vertical support and radial guiding systems, that is, regulation of the vertical support does not give rise to any force component in the radial guiding and conversely, radial movements of the rotor axis do not produce disturbance in the vertical direction.

In contrast, in the known magnetic rotor mounting system, the vertical support is passive, i.e. unregulated, whereas the radial guiding is active. By virtue of its passive vertical suspension, this known system has disadvantages. With the use of permanent magnets for the vertical support, with a viable size of permanent magnet, it is only possible to support a rotor of limited weight. Further, it is in principle necessary for the two cooperating parts of the vertical support system to engage spatially into each other. By using unregulated electro-magnets instead of permanent magnets, it is possible to support a relatively heavy rotor, but here also, the parts must in principle engage spatially into each other. In any case, with this construction of vertical support, decentralising forces are produced in the radial guiding, which increase with any increase in rotor weight. There is therefore quite considerable inter-relation of vertical support and radial guiding. Without active radial guiding the inter-engaging parts of the magnet system would touch each other, for example at the inner edge of the support magnet, immediately up on deviation from the required rotor position. Therefore, considerable radial forces are necessary to urge the rotor into its required position. In addition, for interference forces which may arise in the radial direction, stabilising forces have to be applied. Further, with passive vertical support, no exact vertical operating location can be ensured. Nevertheless, for reliable physical separation, accurate vertical operating location is important. Vertical oscillations which may occur, particularly in the case of a multi-stage rotor, may not be adequately damped. For this reason, an axially acting driving motor is unsuitable for a rotor of this type.

The invention does not merely replace a passive vertical support with an active vertical support. The combination of the active electromagnetic support system and the active radial guiding system provides for virtually complete absence of feed-back between the vertical and radial directions. Thus, the above-mentioned difficulties are largely avoided and a multi-stage rotor can be used. When passing through flexion-critical rotary speeds, the necessary radial guiding forces can be applied without difficulty. Oil dampers in the mountings are not required, since all rotor oscillations can be electrically damped.

The invention offers considerable advantages in both directions, i.e. vertical and radial. Firstly, in the vertical direction, according to requirements, it is possible accurately to predetermine the operating location, which is maintained constant by regulation of the gap. This is particularly important if, by virtue of the high rotary speeds, variations in length of thes rotor occur and have to be compensated for in operation. Further, during running-up and during operation at nominal speed, it is possible at any time, arbitrarily or automatically to vary the position of the rotor. Also high weights of rotor can be accommodated. It is also possible to control the vertical support whenever required and to make damping adjustable substantially at will.

Radial guiding can, according to requirements, be carried out in a desired number of planes whereby, according to a feature of the invention, the several planes can be spaced along the axis of the rotor at heights which correspond to the needs dictated by the control requirements. Of a plurality of radially acting devices, some, and at least two, can be used for radial guiding and damping, while the others are used only for damping. Division of the purposes of the radially acting devices can be determined according to requirements. According to a further feature of the invention, it is possible to construct a radially acting device with separate coils distributed around the periphery of the rotor, or with annular coils.

Another feature of the invention resides in the static and dynamic bearing properties being adjustable virtually at will, because it is possible without difficulty to act on the control circuit of a radially acting system and thus modify its dynamics. For example, during running-up, particularly in the case of a hypercritical rotor, in some cases changes in the damping conditions may be desirable for negotiating flexion-critical rotary speeds. Such a change in the dynamics can if necessary be carried out in a simple manner automatically or arbitrarily, continuously or step-wise, for example according to the rotary speed.

A further advantage of the invention is that the choice of electric driving motor is not subject to limitation in principle concerning its type. The motor may act on the rotor axially or radially as desired. Axial rotor motion which can occur when an axial drive motor is switched on or off, can

be regulated out by the active vertical support system.

An embodiment of the invention will now be described by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic axial section of a gas ultra-centrifuge;

Figure 2 is a diagrammatic cross-section on a radial plane I-I of Figure 1, with separate coils;

Figure 3 shows a modified form of Figure 2, using a single annular coil 1; and

Figure 4 shows a further development of Figure 1, with a multi-stage rotor.

Figure 1 illustrates a gas ultra-centrifuge as an example of a contactless rotor assembly. A rotor 2 is disposed in a fixed housing 1. The rotor is driven by a diagrammatically indicated axial motor 3, the drive taking place through a rotor disc 4 which is rigidly connected to the rotor 2. This drive system is known and need not be described in detail. To reduce gas friction, the centrifuge rotor 2 runs in a vacuum. The evacuated space between the housing 1 and the rotor 2 is identified by 5.

The rotor 2 is freely suspended under a supporting magnet system 7 by a support body 6. The magnet system 7 is a pot magnet. The distance between the magnet system 7 and the support body 6 is sensed by a contactless movement sensor 8 and is fed to a controller 9 as a value. By virtue of an input member 10 connected to the controller 9, a required spacing between the support body 6 and the magnet system 7 can be pre-set, the controller output being connected to the coil of the magnet system 7, as shown.

The support body 6 opposite the magnet system 7 has a convex upper surface whose radius is sufficiently large that pendulum movements of the rotor 2 with respect to the fixed magnet system 7 occasion virtually no change in the present spacing.

The rotor 2 is radially guided in two planes I-I and II-II. In contrast to the system disclosed in our co-pending Application, radial guiding is in this case active. In Figure 1, the section plane of the part to the left of the axis of rotation is indicated by the line A-A in Figure 2, whereas that of the part to the right of the axis in Figure 1 is indicated by the line B-B in Figure 2. Movement sensors 11*a*, 11 *b* for the two axial planes A-A and B-B are in the plane I-I. More detailed information about the location of the movement sensors in the plane I-I and their connection to the associated controller 12*a*, 12*b* and the magnetic coils 13 will be given below.

Radial guiding in the plane II-II is achieved correspondingly, by movement sensors 21*a*, 21*b*, controllers 22*a*, 22*b*, and magnetic coil 23.

In greatly simplified form in Figure 2, the rotor 2 is shown in cross-section as a circle. The movement sensors for the vertical plane A-A, namely the two sensors 11*a*, are connected to their associated controllers 12*a*. Correspondingly, from the controller 12*a*, connections also lead to the pair of magnetic coils 13*a* associated with the plane A-A. The arrangement of the pair of sensors 11*b* with the associated controller 12*b* for the vertical plane B-B is similar. In the present embodiment, two pairs of separate coils 13*a*, 13*b* are staggered 90° about the rotor periphery, as shown. The invention is however not limited to this arrangement and different coil combinations and locations can be used.

In greatly simplified form, Figure 3 again shows, for one plane — e.g. plane I-I — the use of an annular coil 13 in place of the separate coils of Figure 2. Since the locations of the movement sensors and controllers are the same as in Figure 2, they are indicated here only diagrammatically by the controller 12.

Figure 4 shows a multi-stage rotor 2 which is sub-divided in the axial direction by bellows units 2'. This embodiment is intended to show that radial guiding in more than two planes is possible, and planes I-I, II-II, III-III and IV-IV are shown. More such planes may be required if — as indicated by the broken central stage in the rotor 2 — still further rotor stages are incorporated. For simplicity, in the individual planes, only the associated coils 13, 23, 33 and 43 are indicated. The regulating arrangements for the coils and their location should be carried out in accordance with Figures 1 to 3. For simplicity, they have been omitted. Likewise, it is not indicated which of the planes are intended for radial guiding and damping, and which are intended for damping only. The location of the annular coils along the axis of the rotor can be determined in accordance with requirements.

WHAT WE CLAIM IS:—

1. A contactless rotor assembly comprising an elongate rotor having a vertical axis of rotation, an electromagnetic support system for the rotor, and an electromagnetic radial guiding system, the rotor being suspended by the magnetic action of the support system on it, wherein

i) the electromagnetic support system is regulated in accordance with changes in the vertical position of the rotor;

ii) the electromagnetic radial guiding

system provides guiding of the rotor in at least two vertical planes; and

iii) the electromagnetic radial guiding system is regulated in accordance with changes in radial position of the rotor.

2. An assembly according to claim 1, wherein the rotor has more than one stage.

3. An assembly according to claim 1 or claim 2 having two or more radial guiding systems respectively in separate parallel planes disposed along the axis of the rotor.

4. An assembly according to claim 3, wherein at least two of the radial guiding systems are used for radial guiding and radial damping, other radial guiding systems if present being used only for radial damping.

5. An assembly according to claim 3 or claim 4, wherein discrete individual coils are distributed around the rotor in the parallel planes.

6. An assembly according to claim 5, wherein at least two pairs of oppositely disposed individual coils are located pair-wise and staggered by 90°.

7. An assembly according to claim 3 or claim 4, having an annular coil in each parallel plane.

8. An assembly according to any preceding claim, wherein the radial guiding parameters can be varied arbitrarily or automatically.

9. An assembly according to any preceding claim, wherein the vertical support parameters can be varied arbitrarily or automatically.

10. A contactless rotor assembly constructed and arranged substantially as herein described and shown in the accompanying drawings.

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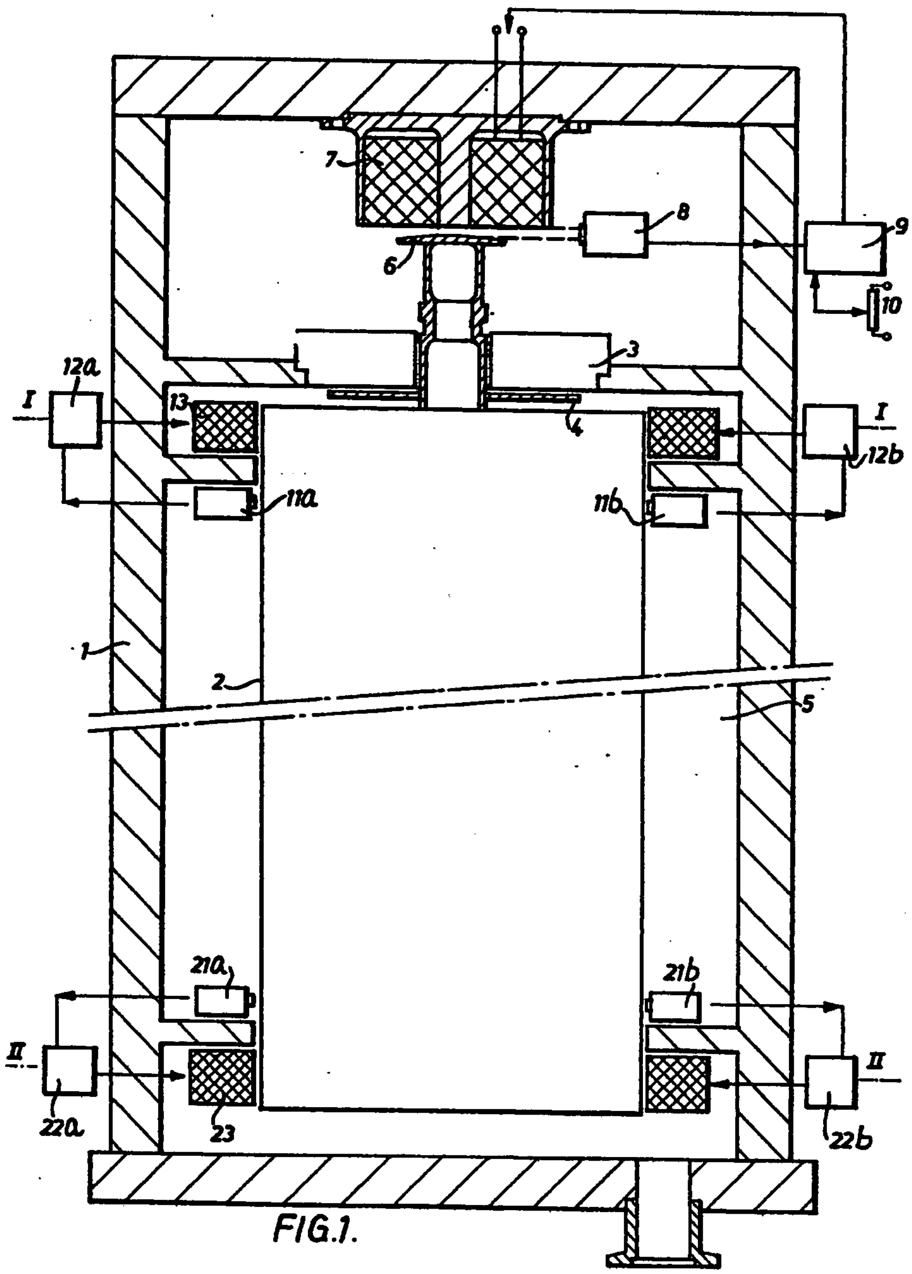

FIG.1.

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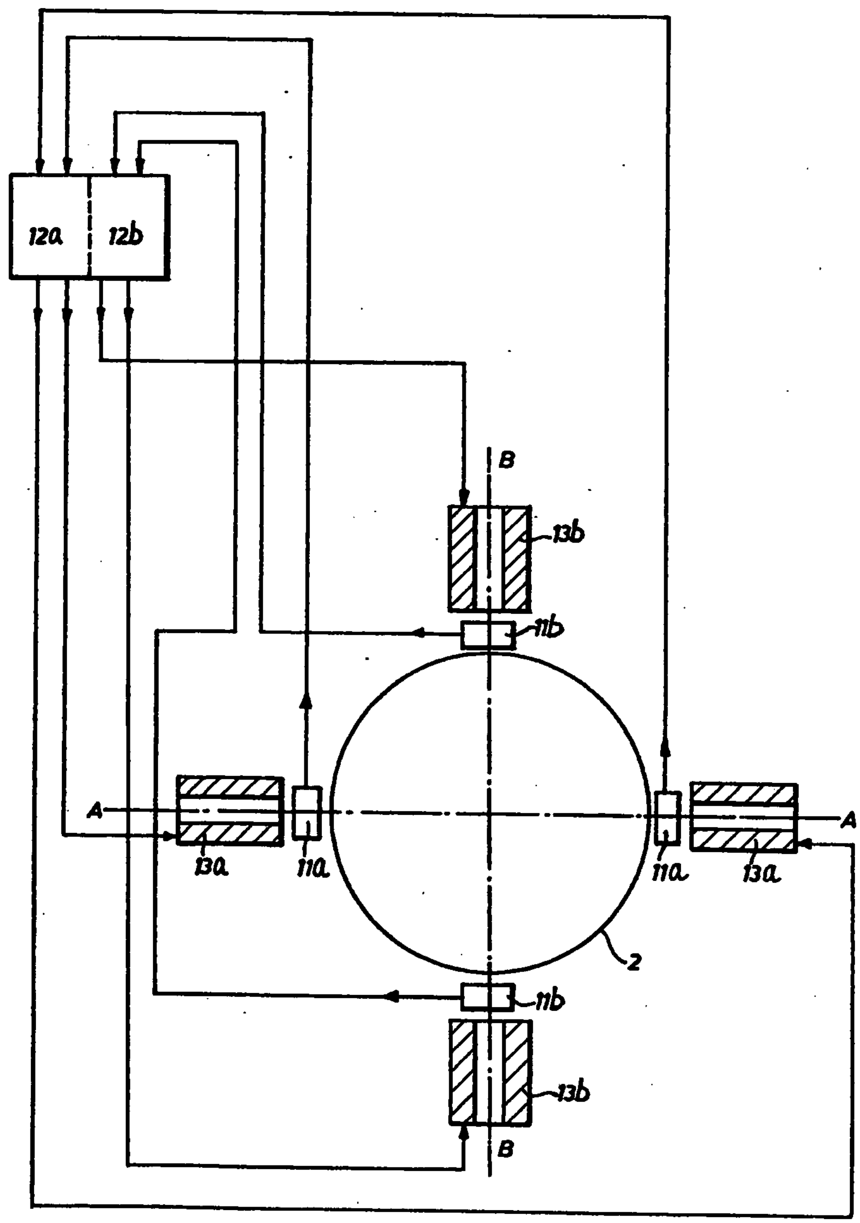
SHEET 2

FIG. 2.



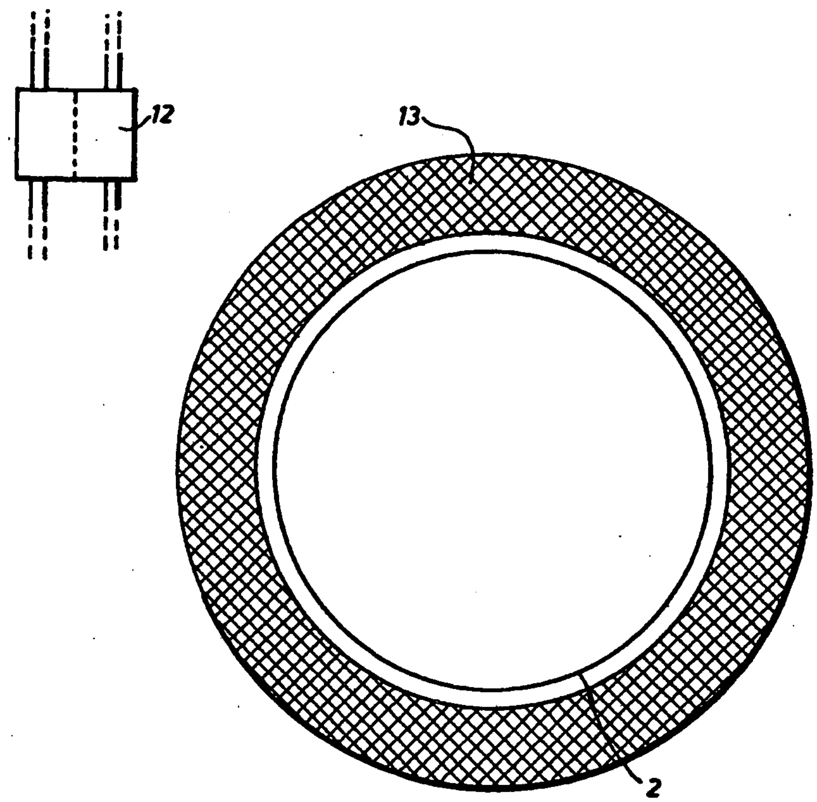


FIG. 3.

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SHEET 4

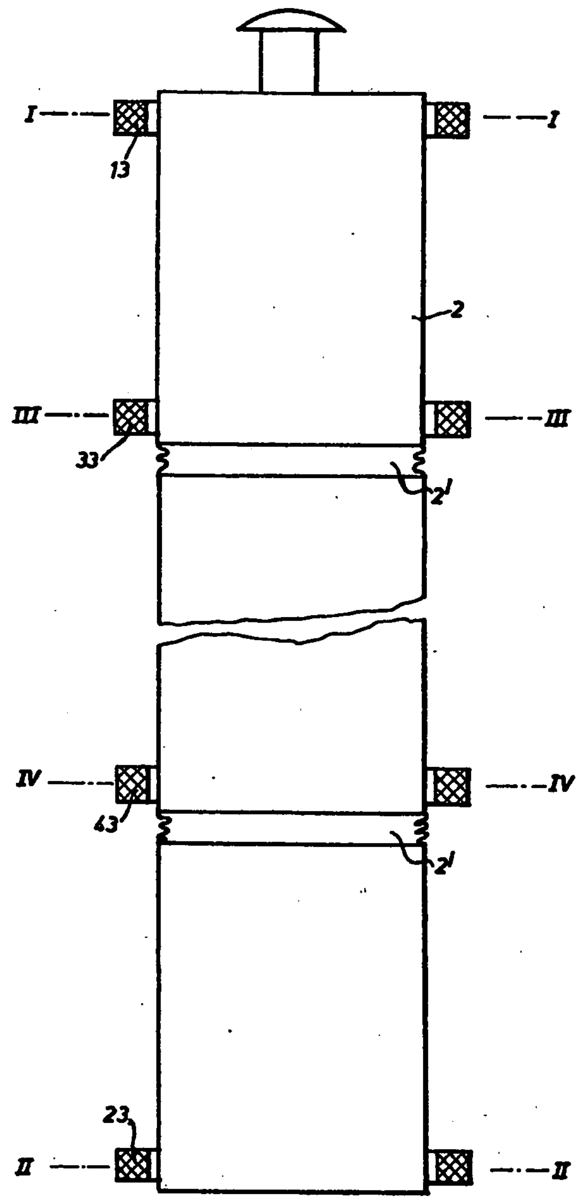

FIG. 4.